

## **COST-EFFECTIVE APPROACH FOR THE MANUFACTURE OF FIBRE METAL LAMINATES (FML)\***

B.S.Sugun , RMVGK Rao and D V Venkatasubramanyam

FRP Division, National Aerospace Laboratories, Bangalore, India, sugun@css.nal.res.in

**ABSTRACT:** *The present work discusses an improved process for the manufacture of fibre metal laminates. Fibre metal laminates are super composite materials combining several properties of fibre and metal layers that constitute them and having potential applications in engineering industry and general purpose industrial applications. Literature information available for preparation of fibre metal laminate are expensive and require huge investment for laminate preparation. The present work provides a simple, cost effective and widely adaptable process for the manufacture of fibre-metal laminates. Here, the metal surface is roughened with grit blasting for obtaining strong bond between metal and fibre cloth adhesive layers (Prepreg) as against the regular chemical pre-treatment process. Also, the prepreg layers are prepared in-house using RTM process. The thus prepared prepreg layers and the pre-treated metal layers are bonded together by a combination of heat (in a regular thermal over) and pressure (obtained by closed mould process). Mechanical properties evaluated show acceptable properties for the prepared laminates.*

### **1. INTRODUCTION**

The development of new materials for the aerospace industry is painstakingly slow due to their need to perform better than the currently being used counterparts. Also, stringent qualification requirements makes this task even more daunting, by way of extensive tests required both at the coupon level and component level. Recently, the development of Fibre Metal Laminates (focussing the issue of cyclic fatigue loading in fuselage structures) as a prospective aircraft material, by Delft Institute of Technology, Netherlands, opened a new arena of research in aerospace technology. It is said that, since the first flight of the Wright Brothers in 1903, this is only the third time that the aviation industry is seeing a new material viz., in the 1930's transition from wood and fabric to Aluminium, in the 1970's utilization of composites, and now (2001) use of GLARE (Glass Reinforced Aluminum Laminate) – a variant of FML in the top fuselage of a passenger aircraft (A 380)<sup>[1]</sup>. Figure 1 shows a schematic of GLARE 4b 3/2 lay-up.<sup>[2]</sup> The current manufacturing route adopted world-wide for GLARE fabrication involves the use of thin aluminium 2024-T3 layers bonded together with S2 glass fibres in FM 94 adhesive system. The system is cured in an autoclave cycle with a maximum pressure of 6 bar and a curing temperature of 120°C<sup>[3]</sup>. The above method calls for high investment and infrastructure requirements suitable in such applications where performance overrides cost. With the advent of such materials, gradually, the focus shifts to its possible usage in less stringent high volume sector applications with due considerations given to the economic advantages that could be exploited. In such a situation, it is required to develop viable alternatives without compromising on the major advantages which the material has got to offer, as then, cost vis-à-vis performance becomes important. In addition to the well established Autoclave Process of manufacturing FML, atleast three other processes viz., stamp forming process<sup>[4]</sup>, RTM Process<sup>[3]</sup>, lamination by the use of hot press<sup>[5,6]</sup> have been reported in literature domain and patent searches. These processes have demonstrated the viability of economising the fabrication process of FML but of course with their limitations. With this back drop, this paper describes yet another simpler process for the manufacture of FML with flat and simple curvatures.

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\* patent filed vide 0056DEL 2008 in India

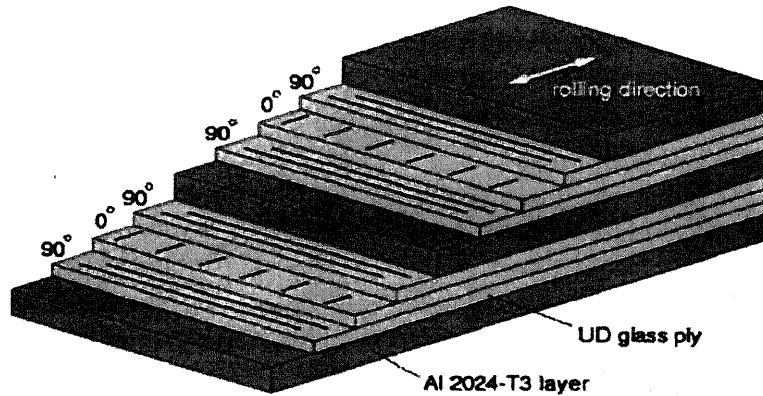
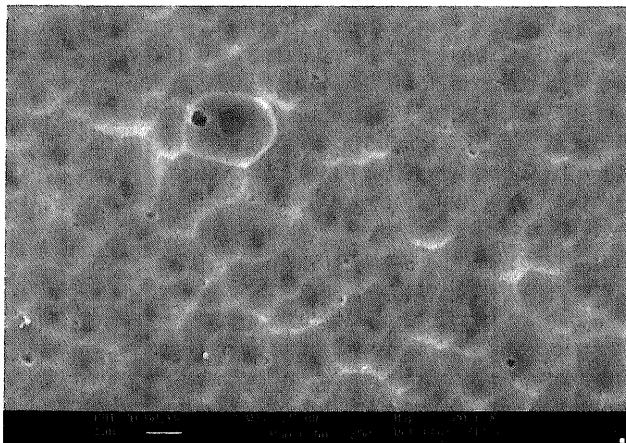


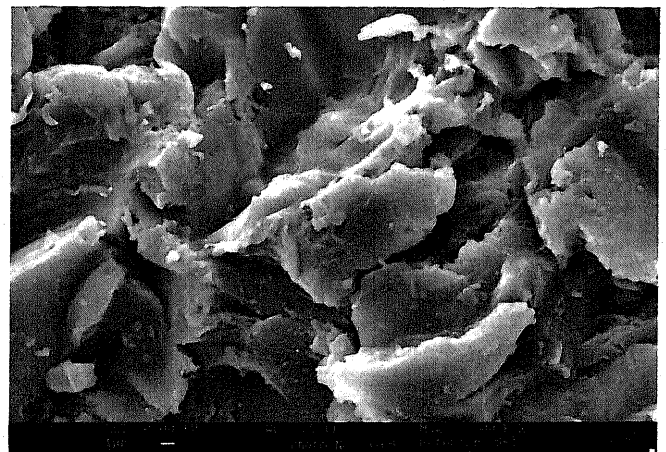
Fig. 1 Schematic of a GLARE 4B 3/2 lay-up<sup>[2]</sup>

## 2. METAL PRE-TREATMENT

The conventional metal pre-treatment comprises of a chemical process wherein the thin metal (either aluminium or titanium) layers are anodised and etched. The aluminium sheets used in the production of fibre metal laminates are anodized and coated with a corrosion inhibiting primer prior to the bonding process<sup>[7]</sup>. In another process, an amorphous chromate coating surface treatment has been carried out on the aluminium alloy prior to laminating.<sup>[8]</sup> In another case, for laminates based on Mg, the magnesium alloy sheets were lightly abraded using a 1200 gritting paper and cleaned with acetone.<sup>[9]</sup> Information from the above literature and such others show that surface preparation of the metal layers for adhesion is important. In the current work 0.4mm aluminium sheets(2014-T6) are used and two types of pre-treatments viz., chromic acid anodizing and grit blasting are tried out. The SEM photograph shows the difference in surface characteristics of the anodized and grit blasted surface as against the untreated surface. It can be observed that in the case of grit blasting, roughening occurs to a major extent in contrast to the minute pits formed by the anodizing process.



Anodised



Gritblasted

Fig. 2 SEM photographs of anodized and gritblasted aluminium sheets

### 3. FIBRE CLOTH ADHESIVE (JUST-IN-TIME PREPREG -- JIPREG) PREPARATION

The fibre cloth adhesive is prepared using 4 mil glass cloth layers ( 1 mil =1/1000 of an inch) and epoxy matrix system ( LY 556, HY 951). Resin ingress technique (figure 3), a variant of RTM process is used for the manufacture of JIPREG. Alternate layers of glass cloth and Teflon sheets are stacked in the closed mould and resin ingress has been carried out as depicted in the self explanatory diagram. Once the ingress is complete, the curing of the matrix system is retarded by immediately deep freezing the mould plates at -18°C for 24 hours. Subsequently, the mould is released and the tacky layers along with the Teflon sheets is wrapped in a polythene sheet and deep frozen for further use. These types of prepregs prepared without any additives or preservatives are termed Just-in-time Prepregs (JIPREGS) due to their very short shelf life. In a related study, on an equivalent resin system, it is found that these JIPREGS can be stored upto 20 days without any observed change in their properties<sup>[10]</sup>.

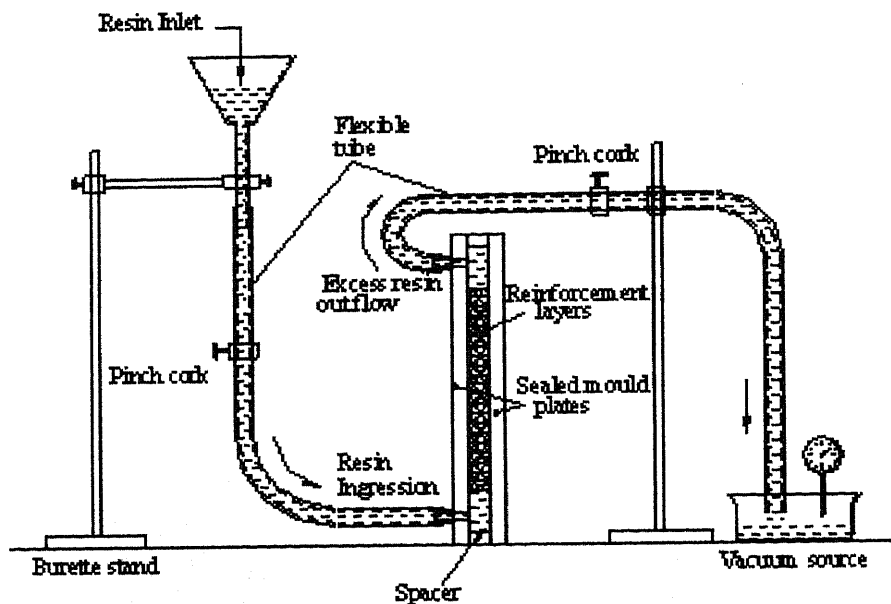


Fig. 3 RIT process for the manufacture of fibre cloth adhesive layers.

### 4. BONDING AND CONSOLIDATION

In the conventional process, the cure consolidation and bonding of the metal and prepreg layers are carried out in an autoclave. In this work, cure consolidation of FML samples are carried out using a closed mould process. 4 layers of the pre-treated metal layers are stacked alternately with 3 layers of JIPREG layers. The JIPREG layers are taken out of the deep freezer, allowed to come to room temperature and carefully separated from the Teflon sheets prior to stacking. Two sets of 4/3 GLARE laminates of 0.25m X 0.22m and 2 mm thick laminates depending on the pre-treatments of the metal layers described above are prepared. The stacked layers are bonded together by the combined pressure applied by the closed moulds and simultaneous curing of the laminates. The laminates are cured according to the cure cycle of the matrix system viz., 50°C for ½ hour, 70°C for 1 hour and 85°C for 2 hours. The metal to fabric layer bonding is achieved by the combination of heat, curing of the matrix system and the pressure of the closed mould plates.

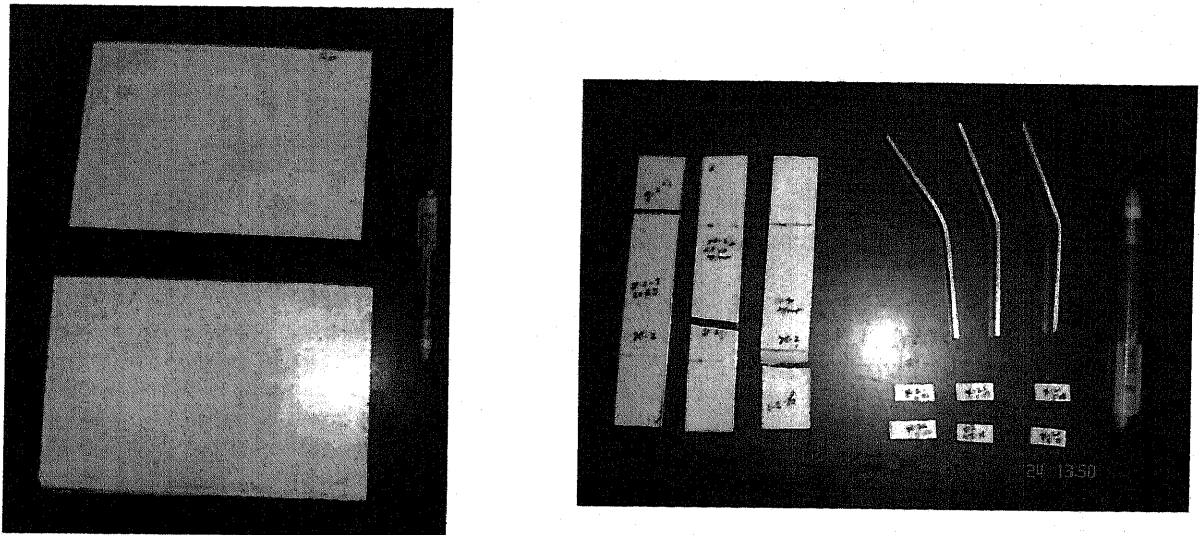
## 5. RESULTS AND DISCUSSIONS

Mechanical properties were evaluated on these specimens using Instron universal testing machine. Table 1 shows the values obtained for the laminates with the two pre-treatments . All the tests were carried out according to the designated ASTM standards ( Tensile - D 3039, Compression - D 3410, Flexural – D 790 and ILSS – D 2344). The test results displayed are an average of atleast 3 specimens in each case.

**Table 1 Mechanical properties of GLARE Samples**

Test details	GLARE sample with ANODISED metal layers	GLARE sample with GRIT blasted metal layers
Tensile ( $\text{kg/mm}^2$ )	44.19	42.78
Compression ( $\text{kg/mm}^2$ )	41.84	35.31
Flexural ( $\text{kg/mm}^2$ )	79.46	85.32
ILSS ( $\text{kg/mm}^2$ )	5.38	4.54

From the table, it can be seen that there is a marginal deterioration of the properties in the case of GLARE samples with grit blasted metal layers. This can be attributed to the surface erosion which is comparatively severe as compared to that of GLARE samples with anodized metal layers. This can be confirmed from the SEM photographs in figure 2. Flexural strength in the case of Grit blasted FML samples has shown improvement because of better adhesion between fibre adhesive layers and aluminium layers which can again be attributed to the increased surface roughness. Figure 4 shows the photographs of the fabricated laminates and the tested specimens. To study the feasibility of the above process for simple curvatures, two curved samples were tried out using the above process. Figure 5 shows the photographs of the formed GLARE samples



**Fig 4 Photographs of fabricated laminates and the tested specimens**

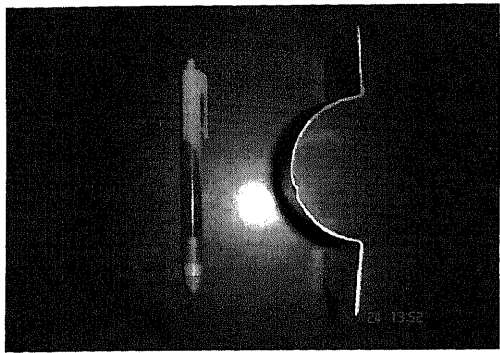
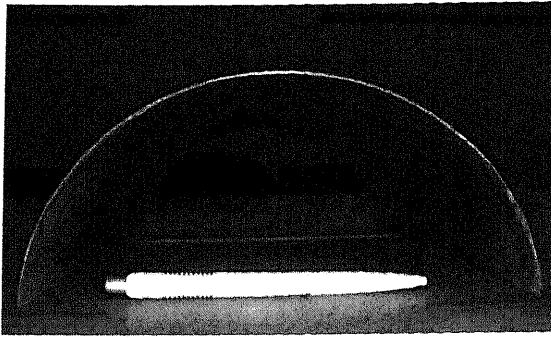


Fig 5 Photographs of simple curved GLARE specimens.

## 6. CONCLUSIONS

This paper describes a simple and cost effective process for the manufacture of fibre metal laminates.. This is done by using alternative metal pretreatment, use of JIPREG and cure consolidation by closed mould process. The cost reduction in the above process can be envisaged in three stages viz., use of grit blasting for metal pre-treatment, use of in-house prepared fibre cloth adhesive layers thus saving on import costs and storage facilities for prepregs, cure consolidation by closed mould process (an out-of-autoclave approach) thus saving on the autoclave costs.

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